The Status of Fiber Optics

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The past decade has witnessed dramatic changes in the communications industry and specifically the fiber optics industry. The markets, technology, and manufacturing infrastructure have gone through what may be one of the greatest expansion phases and the corresponding consolidations. Companies like Worldcom were formed, grew to be comparable to AT&T and have now filed for protection under bankruptcy law. In this paper, I will discuss some of the issues from a market and technology perspective that lead to these changes.

The single greatest enabling technology of the fiber optics industry was the erbium doped fiber amplifier (EDFA). The EDFA was developed in the 1990 time frame and with its development came a technology that was able to amplify 100's of optical channels simultaneously at a cost structure orders of magnitude below that of regeneration. Two technologies were necessary to realize the EDFA, the Er doped fiber and the high power semiconductor lasers used for pumping of the fiber. Initially the fiber was pumped exclusively by 1480 nm lasers as they were more reliable in the early 1990's, however through process improvements, reliable 980 nm lasers became the dominant pump source for EDFAs as 980 nm lasers enable high channel count, low noise EDFAs.

These initial innovations resulted in the deployment of EDFA technology in both undersea and terrestrial systems. Their benefits of cost structure far outweighed the downside of only being a 1R device. In the 1995-6 timeframe companies like Ciena, Lucent and Pirelli started aggressively deploying dense wavelength division multiplexed (DWDM) systems operating at 2.5 Gbits/sec/channel. Nortel subsequently pushed the data rate to 10 Gbits/sec and became the dominant supplier of DWDM transport equipment.

Also, in the 1995-6 timeframe, the fiber plant was dominated by SMF fiber and the transition from the regeneration systems to the EDFA based systems, in conjunction with the expansion of the internet, caused a massive buildout of networks. Key dynamic changes happened in the pre and post 1995 timeframe including the deployment of high fiber count cables. Prior to 1995 most deployed cables had less than 24 fibers in them, after the 1995 timeframe most newly deployed fibers had channel counts of 144 fibers, and in the metro networks fiber counts of 900 fibers were being deployed. This was economical as the cost of deployment was dominated by construction costs and not the cable itself. As a result, the problem of maximizing the capacity in the fiber, which existed in 1995, does not exist now.

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Several key technologies, other than the EDFA, were also critical to the development of the fiber optics business. These included LiNbO based modulators for controlled chirp 10 Gbit/sec transmission, dispersion management via dispersion compensating fibers to manage the analog characteristics of the EDFA based system, and optical muxing technologies. Second generation advances included the demonstration of Raman amplification, which was the enabler of ultra long haul networks, and 40 Gbit transmission technologies for even greater capacity benefits.

In the 2000-2001 timeframe, the economic infrastructure of the fiber optics industry began to unravel. With over $700B invested into communications in the second half of the decade, it became apparent that much of the build out was financed by investors and not through consumer spending. The consumer demand, although growing at 100% per year, was not sufficient to justify the level of capital infrastructure that was implemented. The current state of the market is such that the highest order bit is cost reduction. The market can no-longer support the cost infrastructure and is therefore dramatically limiting the expansion of the networks.

The challenge of the network in the future will be to drive dramatic cost reductions through both better manufacturing infrastructures and better technology choices. It is my opinion that the next phase of the fiber optics industry will be one where the advantages of Si electronics contribute to a lower cost structure. The first areas where Si will impact will be in the incorporation of FEC and electronic equalization. These two technologies can solve as much as 12-15 dB of the link budget. This will enable the optical manufacturer to choose technologies that are lower in performance and therefore lower in cost. The net result will be a resurgence in the industry as the cost infrastructure will become commensurate with the elasticity of the market.

In conclusion, the fiber optics industry has been driven by innovation. Much of this innovation was based on basic materials and device development. The interplay of materials science and device design has resulted in this technology revolution. I would like to thank my thesis advisor, Lester Eastman for his insight into this relationship between materials and devices and his undaunted enthusiasm for innovation.